

# Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/SE04/002050

International filing date: 30 December 2004 (30.12.2004)

Document type: Certified copy of priority document

Document details: Country/Office: US  
Number: 60/545,175  
Filing date: 18 February 2004 (18.02.2004)

Date of receipt at the International Bureau: 24 March 2005 (24.03.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)



World Intellectual Property Organization (WIPO) - Geneva, Switzerland  
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse

PA 1288182

SE/04/2050

# THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

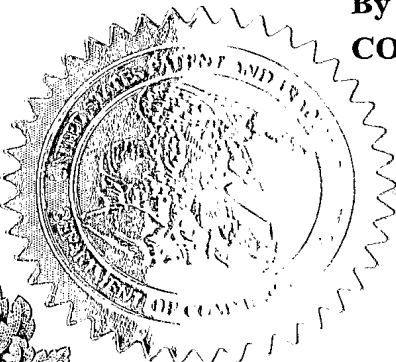
February 28, 2005

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: 60/545,175

FILING DATE: February 18, 2004

By Authority of the  
COMMISSIONER OF PATENTS AND TRADEMARKS



P. SWAIN  
Certifying Officer

19281  
US PTO

# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

## INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and State or Foreign Country)
Ari	KANGAS	

☐ Additional inventors are being named on the \_\_\_\_\_ separately numbered sheets attached hereto

## TITLE OF THE INVENTION (500 characters max)

PSEUDORANGE RECONSTRUCTION

## CORRESPONDENCE ADDRESS

Direct all Correspondence to:

☒ Customer Number

00466

Type Customer No. Here

Firm Name & Address:

Young & Thompson  
745 South 23<sup>rd</sup> Street  
Arlington, VA 22202  
USA

Telephone: 703-521-2297 - Facsimile: 703-685-0573

## ENCLOSED APPLICATION PARTS (check all that apply)

<input checked="" type="checkbox"/> Specification	Number of Pages:	9	<input type="checkbox"/> CD(s), Number.	
<input checked="" type="checkbox"/> Drawings	Number of Sheets:	3	<input type="checkbox"/> Other (specify)	
<input checked="" type="checkbox"/> Application Data Sheet				

## METHOD OF PAYMENT OF FILING FEES FOR PROVISIONAL APPLICATION FOR PATENT

- ☐ Applicant(s) claims small entity status.
- ☒ A check is enclosed in the amount of **\$160.00** for the filing fee.
- ☒ The Commissioner is authorized to charge any underpayment or credit any overpayment to Deposit Account No. 25-0120

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

- ☒ No
- ☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

Docket No.: **1510-1082**

By: Benoit Castel  
Benoit Castel, Reg. No. 35,041

Date: **February 18, 2004**

BC/ia

PROVISIONAL APPLICATION FILING ONLY

Y&T February 16, 2004

## Application Data Sheet

### Application Information

Application Type::	Provisional
Subject Matter::	Utility
Suggested Classification::	
Suggested Group Art Unit::	
CD-ROM or CD-R?::	None
Number of CD disks::	
Number of Copies of CDs::	
Sequence Submission?::	None
Computer Readable Form (CRF)::	No
Number of copies of CRF::	0
Title::	PSEUDORANGE RECONSTRUCTION
Attorney Docket Number::	1510-1082
Request for Early Publication?::	No
Request for Non-Publication?::	No
Suggested Drawing Figure::	
Total Drawing Sheets::	3
Small Entity?::	No
Latin Name::	
Variety Denomination Name::	
Petition Included?::	No
Petition Type::	
Licensed US Gov't Agency::	
Contract or Grant Numbers::	
Secrecy Order in Parent Appl.?::	No

**Applicant Information**

Applicant Authority Type:: Inventor  
Primary Citizenship Country:: SWEDEN  
Status:: Full Capacity  
Given Name:: ARI  
Middle Name::  
Family Name:: KANGAS  
City of Residence::  
State or Province of  
Residence::  
Country of Residence::  
Street of Mailing  
Address::  
City of Mailing Address::  
State or Province of Mailing Address::  
Country of Mailing Address::  
Postal or Zip Code of Mailing Address::

**Correspondence Information**

Correspondence Customer 000466  
Number::

**Representative Information**

Representative Customer	000466
Number::	

**Domestic Priority Information**

Application::	Continuity Type::	Parent Application::	Parent Filing Date::

**Foreign Priority Information**

Country::	Application Number::	Filing Date::	Priority Claimed::

**Assignment Information**

Assignee Name::

Street of Mailing

Address::

City of Mailing Address::

State or Province of Mailing Address::

Country of Mailing Address::

Postal or Zip Code of Mailing Address::

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen		
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A	Reference

## Pseudorange reconstruction

### 1 Name Of Invention

Pseudorange reconstruction

### 2 Inventor

EAB/TUD/P Ari Kangas

### 3 Summary of invention

This invention is in general related to methods for locating user equipment (UE) by using a satellite navigation system like GPS (Global Positioning System), see [1] or [2]. In particular it addresses some specific problems that arises in assisted GPS ([3]) in situations where the initial uncertainty of the location of the UE is large, in a sense that will be described later. Assisted GPS in general aims at improving the performance of GPS receivers in many different respects, including coverage, time to obtain a location estimate, and saving battery power. In general this is done by moving some functionality from the GPS receiver to the network and only perform a subset of the GPS tasks in the receiver itself. However one side-effect is that a rough apriori information about the receiver location is needed to reconstruct certain range measurements that are not completely done by the UE. This invention addresses in particular the problem of range measurement reconstruction in cases where the initial location uncertainty is too large for prior art solutions to work properly. A recursive procedure is proposed where the unlikely range measurements are sequentially discarded based on optimization criteria.

### 4 Background to the invention

The GPS Space Vehicles (SVs) transmit ranging signals with a spectrum centered at 1575.42 MHz. The signals include a so-called Coarse/Aquisition (C/A) code that is unique for each SV. The C/A code has a length of 1023 chips and a chip duration of  $1/1.023 \times 10^6$  s. The C/A code repeats itself every 1 ms. Superimposed on the C/A code is a navigation data bit stream with a bit period of 20 ms. The navigation data includes among other things a set of so-called ephemeris parameters that enables the receiver to calculate the precise position of the satellites at the time of signal transmission. The SVs carry precise atomic clocks to maintain clock stability. The SV transmissions are however not perfectly synchronized to GPS system time, as illustrated in the timing diagram 100 of Figure 1. By drawing a vertical line through the timing diagram 100 one may obtain a snapshot of all clock readings as observed in various points in space. GPS system time 101 is defined as an ensemble average based on a set of ground

Prepared (also subject responsible if other) EAB/TUD/P. Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

station clocks and a subset of SV clocks. The individual SV clocks 102, 103 are slightly offset compared to GPS system time. A model for the individual offsets is transmitted as part of the navigation message from each SV. When the signals reach a UE on the earth surface, they have been delayed with an amount depending on the range from the SV in question to the UE. The delay is typically 60-85 ms as illustrated by the clock readings 104, 105.

The GPS receiver basically measures the pseudorange to a number of satellites. The pseudorange is

$$\rho_i = c \cdot (t_u - t_{ti}) \quad (1)$$

where  $t_u$  is the UE clock 106 reading at the time of reception, and  $t_{ti}$  is the time of signal transmission of the  $i$ th SV (104, 105), and  $c$  is the wave propagation speed. The pseudorange differs from true range with a number of perturbing factors (receiver clock bias, ionospheric and tropospheric delays, SV clock bias, measurement errors, etc). For the purpose of clarity, in this discussion we will neglect the influence of most of these error sources. There are known techniques to compensate for many of the above listed error sources (see [1], [2]). Furthermore the effect of SV movement and earth rotation is also omitted as it is also well known in the art how to handle these effects. The simplified model is then that the measured pseudorange obeys

$$\rho_i = |x_u - x_{si}| + b + e_i \quad (2)$$

Here  $x_u = (x_u, y_u, z_u)$  is a row vector containing the three-dimensional coordinates of the unknown receiver location. Similarly  $x_{si}$  is the row vector containing the coordinates of the  $i$ th SV. The notation  $|z|$  means the norm of the vector quantity within brackets, which is equal to  $(zz^T)^{1/2}$ . In this case it can be interpreted as the distance between the receiver and the SV. Furthermore  $b$  is the receiver clock bias 106 (expressed as a range),

$$b = c \cdot (t_u - t_{GPS}) \quad (3)$$

where  $t_{GPS}$  stands for GPS system time. Finally  $e_i$  is the measurement error.

The transmission time  $t_{ti}$  is typically determined in several stages. Firstly the submillisecond part of  $t_{ti}$  is determined using by determining the boundaries of the C/A codes for each SV (see Figure 1). This is done using correlators that test all possible code phase and Doppler shifts.

In a subsequent step the millisecond part of the transmission time needs to be reconstructed. This normally requires that the received data is despread, leaving raw navigation databits. Timing reconstruction can then be made by a number of techniques.

*Direct demodulation of TOW (Time Of Week).* This requires first that bit synchronization at 20ms level is done. Then the data is demodulated at a rate of 20ms; this process normally requires that subframe boundaries are determined followed by decoding the so-called Handover Word, from which the TOW, ie the transmission time  $t_{ti}$ , can be derived. Each subframe has a length of 6 s, so this procedure may require that approximately 8 seconds of navigation data is collected. TOW demodulation works down to approximately -172dBW, assuming 0dB antenna and is in fact the limiting factor for GPS coverage.

*TOW Reconstruction using correlation techniques.* This procedure also requires that demodulated data bits are generated, but instead of direct decoding, correlation is made with known transmitted navigation data bits (e.g. the contents of the so-called Telemetry Word and the HOW word which may be sent to the UE as part of the assistance data). This requires that the GPS time is apriori known to within a few seconds. This procedure works to somewhat lower signal levels than direct TOW decoding,



Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

but most likely the performance is limited by the tracking loops that may loose lock at such low signal levels. Typically phase locked loops or automatic frequency control loop are employed for this. But it is expected that this will work down to say -179dBW. *Use of real-time clocks.* If TOW has previously been determined the receiver may be able to maintain an accurate clock at a millisecond level using e.g. the cellular system clocks that typically drift only a few nanoseconds per second and long term stability may be better than 1ms for significant time. However it may be difficult for the user to know the absolute accuracy, which limits the use of this method.

In MS assisted AGPS [1] the MS reports only the C/A code boundary locations and an estimate of the GPS system time at time of measurement. Oddly enough the MS is requested to report not the millisecond part of the received SV clock, but instead needs to perform a compensation for the assumed propagation delay. It may therefore be assumed that the inaccuracy in the time stamp could typically be larger than 1ms. There are techniques for estimating the propagation delay down to millisecond level, listed in the copending application.

A further possibility is that the MS does not try to estimate GPS system time at reception time at ms accuracy level. Instead one may use redundant measurements for estimating also the unknown reception time.

The MS in MS assisted AGPS reports only pseudoranges modulo 1 C/A code period, ie the integer number of code periods in the pseudorange (1) is not known. It has to be reconstructed. Let

$$R = c \cdot 10^{-3} \quad (4)$$

denote the range corresponding to one C/A code period. We thus have that

$$\rho_i = k_i R + v_i \quad (5)$$

where  $v_i$  is the reported measurement that satisfies  $0 \leq v_i < R$ , and where admissible values of the integer  $k_i$  needs to be reconstructed. The reconstruction is done in the following way. It is assumed that an apriori location  $r_{u0}$  of the MS is known, along with an uncertainty  $\Delta$ , such that

$$|x_u - x_{u0}| < \Delta \quad (6)$$

First we determine the predicted pseudorange, and divide into an integer C/A part and a fractional part

$$\rho_i' = |x_s - x_{u0}| = k_i' R + v_i' \quad (7)$$

where  $k_i'$  is an integer and  $v_i'$  satisfies  $0 \leq v_i' < R$ . We then define the reconstructed pseudorange as

$$\rho_i^* = k_i^* R + v \quad (8)$$

and take  $k_i^* = k_i'$  as initial value. Next if  $\rho_i^* - \rho_i' > R/2$ , then we set  $k_i^* = k_i^* - 1$ . Else if  $\rho_i^* - \rho_i' < -R/2$  then we set  $k_i^* = k_i^* + 1$ .

When the initial location uncertainty is large, several values of  $k_i$  may be admissible. Furthermore the presence of a common bias term  $b$  makes it difficult to reconstruct the  $k_i$  exactly. However from position calculation point of view it is the relative pseudoranges that matter, since any constant bias term will cancel in the position calculation. Therefore it is desirable to obtain a bound on admissible relative pseudoranges, given the amount of initial location uncertainty. Assuming small measurement errors, we have that

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A.
		Reference	

$$\rho_r - \rho_i = |x_u - x_{si}| - |x_u - x_{st}| \quad (9)$$

To obtain a sharp bound one may calculate the expected range difference at all possible receiver locations that satisfy (6). This way we obtain an inequality.

$$-\Delta_i \leq \rho_r - \rho_i - \delta \rho_i \leq \Delta_i \quad (10)$$

where  $\delta \rho_i$  is the mean value of the maximum and minimum range difference that was found within the uncertainty area. Similarly  $\Delta_i$  is half the difference between the maximum and minimum range difference that was found within the uncertainty area.  $\rho_i^*$  can now be calculated using (8), and an initial value of  $\rho_i^*$  is obtained using the same formula (8). Then it can be checked for varying  $k_i^*$ , whether the (10) is satisfied..

However it may be cumbersome to determine  $\delta \rho_i$  and  $\Delta_i$  explicitly. A simpler way is base the calculations on the individual pseudoranges. Similarly to (10) one may determine  $\rho_i'$  and  $\Delta_i$  that fulfil

$$-\Delta_i \leq \rho_r - b - \rho_i' \leq \Delta_i \quad (11)$$

for all  $x_u$  that satisfy (6). This can be done quite easily by applying simple geometry. Applying the triangle inequality one may then obtain

$$|(\rho_r - b - \rho_i') - (\rho_r - b - \rho_i)| \leq |(\rho_r - b - \rho_i')| + |(\rho_r - b - \rho_i)| \leq \Delta_i + \Delta_i \quad (12)$$

A further simplifying expression may be obtained by using only the relation (6) and the triangle inequality. First note that

$$||x_u - x_{si}| - |x_u - x_{st}|| \leq |x_u - x_{si}| + |x_u - x_{st}| \quad (13)$$

hence

$$\rho_r - b = |x_u - x_{si}| = |(x_u - x_{u0}) - (x_{si} - x_{u0})| \leq |x_u - x_{u0}| + |x_{si} - x_{u0}| \leq \Delta + \rho_i' \quad (14)$$

Secondly note that the triangle inequality also gives that

$$| |(x_{si} - x_{u0})| - |(x_u - x_{u0})| | \leq |x_u - x_{si}| = \rho_i - b \quad (15)$$

Since the distance to the SVs are most likely larger than the uncertainty in location we get that

$$\rho_i' - \Delta \leq \rho_r - b \leq \rho_i' + \Delta \quad (16)$$

Rearranging we get that

$$-\Delta \leq \rho_i - b - \rho_i' \leq \Delta \quad (17)$$

hence

$$|\rho_i - b - \rho_i'| \leq \Delta \quad (18)$$

The relative pseudorange errors are then bounded by

$$|(\rho_i - b - \rho_i') - (\rho_i - b - \rho_i')| \leq |\rho_i - b - \rho_i'| + |\rho_i - b - \rho_i'| \leq 2\Delta \quad (19)$$

Equatons (10), (12) and (19) define three ways to find admissable values for  $k_i^*$ . This is done by replacing the true pseudorange  $\rho_i$  by the reconstructed  $\rho_i^*$ , and varying  $k_i^*$  in the expression (8). In

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

order to have a unique reconstruction of pseudorange it is thus required that only one  $k_i^*$  satisfies the inequalities (10), (12), (19). The possible pseudorange values of the left hand side are in all cases spaced by  $R$  meters. The width of the uncertainty interval for the last example (19) is  $4\Delta$ . So for this case an unique  $k_i^*$  is found whenever  $\Delta < R/4$ .

## 5 Problem

It has been demonstrated above that a unique reconstruction of pseudoranges may in worst case require that the initial location uncertainty is less than  $R/4$ . This amounts to approximately 75 km. There are several cases where it can be assumed that the initial location is not known to that accuracy level. In most cellular standards the initial location and its associated uncertainty is given by the coverage of the serving cell. In GSM the cells may be as large as 100km in so-called extended range mode. For some other applications, it may be foreseen that the MS location is not known at a cell level, perhaps only the Service Area or Location area is known. These areas cover more than one individual cell and may therefore span larger areas than 75km. In other extreme cases maybe only the country of the visited network operator is known. It is therefore desirable to be able to cope with the situation where the initial location uncertainty may cause ambiguities in the reconstruction of pseudoranges.

## 6 Solution

Before we present the solution in detail we will describe the position calculation function in detail. First we express the measurement equation (2) in vectorized form as

$$\rho = |1_n \cdot x_u - X_s| + b + e \quad (20)$$

Here  $\rho$  is the column vector of length  $n$  containing the pseudoranges,  $1_n$  is a column vector of length  $n$  containing only ones.  $X_s$  is a matrix where the  $i$ th row contains the coordinates  $x_{si}$  of the  $i$ th SV. It is assumed here that the norm  $|Z|$  is calculated for each row of the matrix  $Z$  within brackets.

We may now perform a Taylor series expansion around the initial estimate of the unknown parameters  $x_u$  and  $b$ .

$$\rho = |1_n \cdot x_u - X_s| + b + e = |1_n \cdot x_{u0} - X_s| + G \cdot ((x_u - x_{u0}) \ b)^T + v \quad (21)$$

$G$  is the geometry matrix which contains the derivatives of the pseudoranges with respect to the parameters  $x_u$  and  $b$ . Let

$$r_i = |x_{u0} - x_{si}| \quad (22)$$

then  $G$  is a matrix with the  $i$ th row being equal to

$$G_i = [(x_{u0} - x_{si})/r_i \ (y_{u0} - y_{si})/r_i \ (z_{u0} - z_{si})/r_i \ 1] \quad (23)$$

Note that since  $|1_n \cdot x_{u0} - X_s| = G(:, 1:3) \cdot x_{u0}^T$ , (21) may be simplified to

$$\rho = G \cdot (x_u \ b)^T + v \quad (24)$$

The least squares solution to (24) is equal to

$$(x_u \ b)^T = (G^T G)^{-1} G^T \rho \quad (25)$$

The least squares minimum loss function value, is equal to

$$V = \rho^T (I - G(G^T G)^{-1} G^T) \rho \quad (26)$$

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen		
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A	Reference

The minimum loss function value is a measure of how well the predicted pseudoranges based on an updated parameter estimate, match the measured pseudoranges.

Returning now to the problem of pseudorange reconstruction, the complete procedure is outlined in Figure 2. The procedure starts at 201 by calculating a reconstructed pseudorange for an arbitrary SV. Let this pseudorange be denoted  $\rho_1^*$ . Then we compute admissible pseudoranges  $\rho_2^*$  and  $\rho_3^*$  using (10), or (12), or (19). Assuming  $n_2$  and  $n_3$  admissible pseudoranges were found, respectively, then  $n_2 \cdot n_3$  candidate pseudorange vectors can be constructed. In 202 a least squares estimate is performed for each candidate, but since only three measurements are used, only a two dimensional location fix can be made. It is most natural to estimate the x and y coordinates since the apriori uncertainty in the vertical dimension is typically smaller than the horizontal uncertainty. Therefore the third column of the **G** matrix is not used, and we need to use (21) instead of (24), since the simplification leading to equation (24) is not valid in that case.

The reduced parameter vector  $(x_u \ y_u \ b)^T$  is estimated for all candidate pseudorange vectors. In 203 the selection of the most pseudorange vector candidate is done by considering the size of the update step in the horizontal dimension. Hence  $((x_u - x_{u0})^2 + (y_u - y_{u0})^2)^{1/2}$  is determined for all candidate vectors. Since it is known that apriori  $((x_u - x_{u0})^2 + (y_u - y_{u0})^2)^{1/2} < \Delta$  for the true parameter vector  $x_u, y_u$  those candidates that generate an update step significantly larger than  $\Delta$  are excluded from further calculations. The threshold should be chosen somewhat larger than  $\Delta$  to account for the fact that the least squares solution normally has to be performed iteratively, with an updated **G** matrix, since the least squares equation (25) is only an approximation for the original non-linear problem (20). Note that in this case the residual **V** in (26) cannot be used, since it will in most cases be equal to zero in the case of three measurements, three equations.

In the next step 204 it is checked whether all pseudoranges have been reconstructed. If yes, the position calculation function 213 is used for calculation of the UE position. If no, in next step 205 all candidate pseudoranges  $\rho_4^*$  are calculated using either (10), (12), or (19), and a set of all possible pseudorange vectors is constructed. In 206, the loss function value (26) is calculated for all candidate pseudorange vectors, assuming also in this case that only a two-dimensional location vector is estimated. Note that in this step no explicit solution (25) needs to be calculated. In 207, the pseudorange vector that minimized the loss function is kept. Alternatively all vectors that produce a loss function less than a certain threshold is kept.

In the next step 208 it is checked whether all pseudoranges have been reconstructed. If yes, the position calculation function 213 is used for calculation of the UE position. Otherwise, in the following steps, enough measurements are available to enable a three-dimensional solution. The procedure for pseudorange construction is thus repeated in 209 for  $\rho_k^*$  where  $k=5$ . The loss function values is computed in 210 for all admissible pseudorange vectors using (26) with the complete **G** matrix. The most unlikely pseudorange vectors are excluded in step 211 based on the said loss function values. In step 212 it is checked whether all pseudoranges have been reconstructed. If yes, the position calculation function 213 is used for calculation of the UE position. Otherwise the procedure of pseudorange reconstruction and exclusion of unlikely pseudorange vectors is repeated from step 209 for  $\rho_k^*$  where  $k$  is incremented before each new iteration of 209-211. When all pseudoranges have been reconstructed, the least squares solution (25) is determined in step 213, possibly using an iterative scheme.

In Figure 3, an exemplary hardware implementation is shown. The UE 300 consists of a cellular communication module 301, a positioning module 302, an GPS RF front end 303, an antenna 304 for communication with the cellular network and a GPS antenna 305. The cellular communication module 301 receives assistance data from the cellular network. The assistance data could consist of ephemeris

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

and clock corrections for visible satellites, an approximate UE location and an approximate GPS system time. Alternatively the assistance data could contain explicit assistance intended only for assisting the correlation processing. The assistance data is in both cases sent to the positioning module 302 using the interface 306. The communication module 301 also provides the GPS RF front end 303 and the positioning processor 302 with a clock reference 307. The RF front end module 303 is controlled by the positioning processor 302 using interface 308. When the positioning module 302 receives a positioning request from the communication module 301, it instructs the RF front end module 303 to collect GPS signal samples. The GPS RF front end 303 receives the GPS frequency band through the antenna 305, downconverts the signal to baseband, separates the signal into in-phase (I) and quadrature (Q) components, samples and converts the signals into digital format, and outputs these to the positioning processor 302 through interface 309. The positioning processor stores the received I and Q data in memory 310 and after enough data has been collected, correlation operations take place within the DSP 311. After finding at least one correlation peak corresponding to at least one satellite signal, the said signal is despread leaving raw navigation data bits, and the TOW at reception is estimated using any of the techniques described herein. The correlators are controlled by the CPU 312, that in turn uses the assistance data for reducing the amount of correlations needed. When enough C/A code boundaries have been detected, or a timer has elapsed, the positioning module 302 outputs the measured truncated pseudoranges and the estimated TOW to the communication module 301 through the interface 313 that sends the measurements to the cellular network for pseudorange reconstruction and position calculation. Alternatively the pseudorange reconstruction and position calculation may be done in the CPU 312 using available ephemeris and clock correction parameters, approximate GPS system time and the approximate location of the UE.

## 7 Claims Proposal

1. A method for calculation of the location of a user equipment, being able to communicate with a cellular network, user equipment including a GPS receiver, being characterized by;
  - the initial user location being known to be within a specified initial uncertainty area, e.g. as a geographical point with an uncertainty circle.
  - the receiver estimating the truncated pseudorange to a multiple of satellites, by determining the code boundaries of signals transmitted by said multiple satellites.
  - the receiver may optionally reconstruct the complete pseudoranges for some, but not all satellites, using a despread satellite signal.
  - a position calculation functionality wherein the complete pseudoranges are reconstructed for all satellites for which only truncated pseudoranges are available.
  - a position calculation functionality that calculates all possible pseudoranges in situations where the initial uncertainty area is too large to enable unique reconstruction of the said pseudoranges
  - a position calculation functionality that performs location calculations based on all admissible pseudorange vectors, and based on the result of the position calculation, determines the most likely pseudoranges.
  - a position calculation functionality that based on the most likely pseudoranges, determines the location of the user equipment.
2. A method according to 1, further characterized by,
  - the set of admissible pseudoranges being determined by first calculating the range to the center of the initial uncertainty area, and the lower and upper bounds for the range being approximated by using the radius of the initial uncertainty area.
3. A method according to 1, further characterized by,

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen		
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A	Reference

- the set of admissible pseudoranges are being determined by calculating the smallest and largest range from each satellite to any point within the initial uncertainty area.

4. A method according to 1, further characterized by,

- the set of admissible pseudoranges being determined by calculating the smallest and largest range difference between any satellite and a reference satellite to any point within the initial uncertainty area.

5. The method according to 1, further characterized by,

- the set of admissible pseudorange vectors being determined for 3 satellites,  
- a set of possible locations in the horizontal coordinates being determined using the set of admissible pseudoranges  
- the set of admissible pseudoranges being reduced by excluding those pseudorange vectors that led to a horizontal location coordinate sufficiently outside the initial uncertainty area.

6. The method according to 5, further characterized by,

- the set of admissible pseudoranges being determined for a 4th satellite, if such measurement is available  
- the location in the horizontal coordinates being determined using the set of admissible pseudorange vectors,  
- a so-called loss function value, a measure of how well the 4 pseudoranges match, is calculated at all determined locations  
- the set of admissible pseudoranges being reduced by excluding those pseudorange vectors that produced a too large loss function value

7. The method according to 6, further characterized by,

- the set of admissible pseudoranges being determined for the 5th satellite, if such measurement is available  
- the location in three-dimensional coordinates being determined using the set of admissible pseudorange vectors,  
- a so-called loss function value, a measure of how well the 5th pseudoranges match, is calculated at all determined locations  
- the set of admissible pseudoranges being reduced by excluding those pseudorange vectors that produced a too large loss function value

8. The method according to 7, further characterized by,

- the procedure of claim 7 is repeated for satellites 6 to n, where n is the number of satellites being measured by the GPS receiver.

9. The method of claim 8, further characterized by,

- the position calculation functionality residing in the cellular network or any node external to the user equipment.

10. The method of claim 8, further characterized by,

- the position calculation functionality residing in the user equipment.

## 8 References

[1] Navstar GPS Space Segment/Navigation user Interfaces, ICD-GPS-200, Revision IRN-200C-003, 11 October 1999.

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

[2] Parkinson, Spilker Global Positioning System: Theory and Applications, Volume 1, AIAA, 1996

[3] 3GPP TS 44.031, v 5.6.0

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

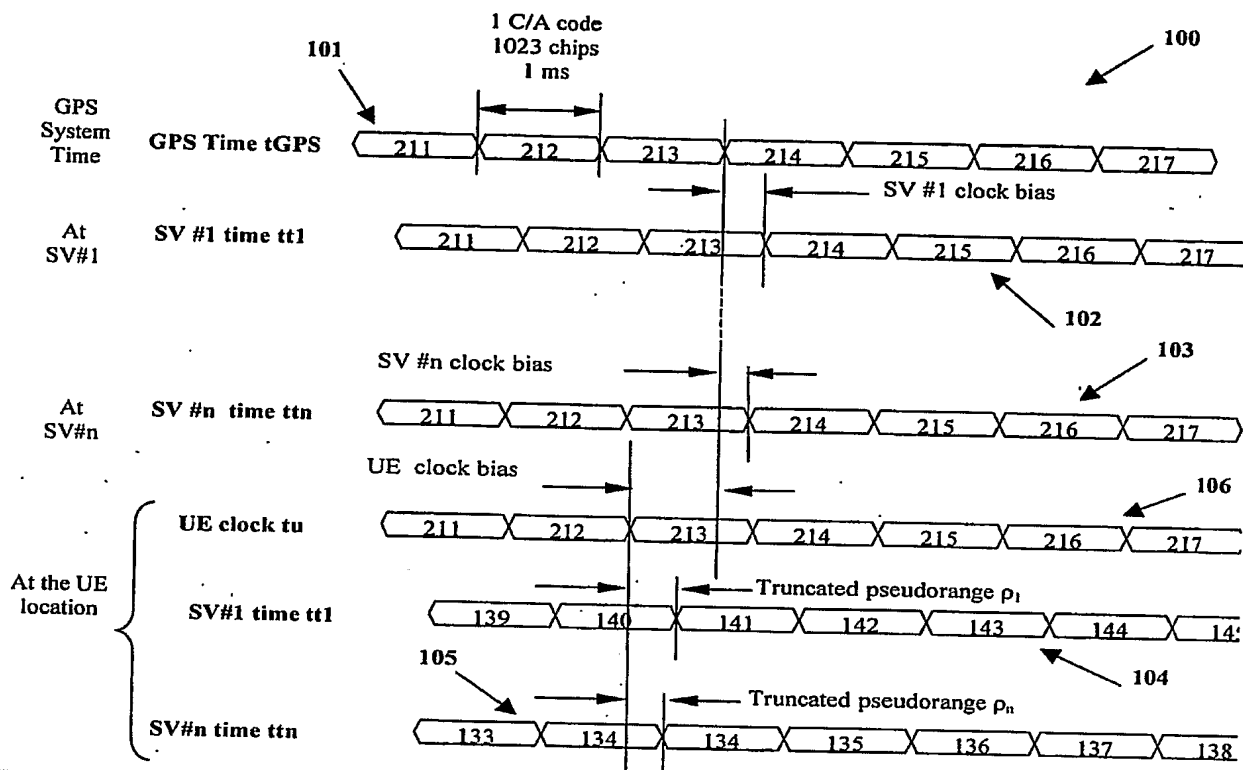


Figure 1. GPS clock definitions



Prepared (also subject responsible if other)

EAB/TUD/P Ari Kangas

No.

EAB/TU-04:000028 Uen

Approved

Checked

Date

2004-02-12

Rev

A

Reference

EAB/TUD/P [Ari Kangas]

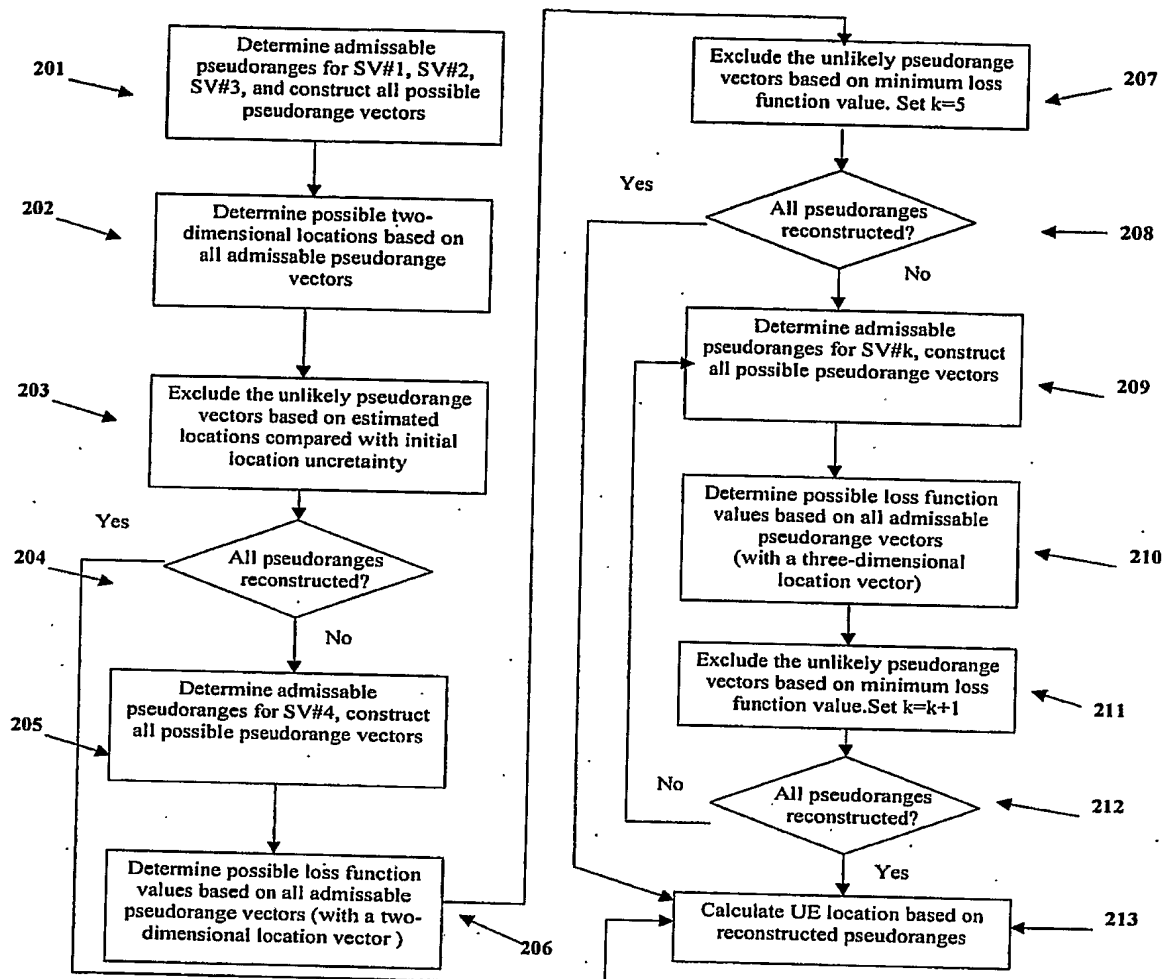


Figure 2. Work flow for pseudorange reconstruction

Prepared (also subject responsible if other) EAB/TUD/P Ari Kangas		No. EAB/TU-04:000028 Uen	
Approved EAB/TUD/P [Ari Kangas]	Checked	Date 2004-02-12	Rev A
		Reference	

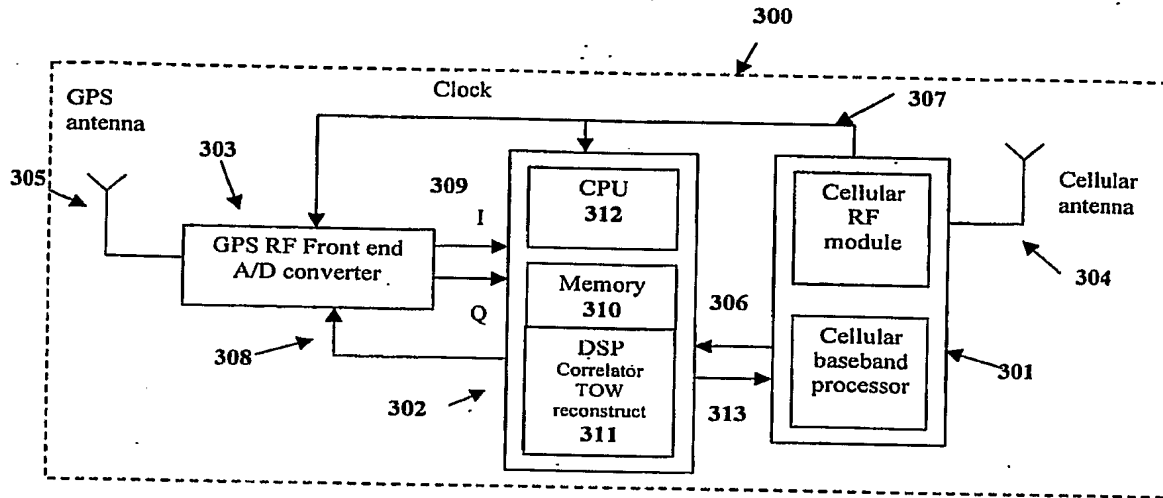


Figure 3. Exemplary implementation